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EQUIVALENCE CLASS FORMATION IN A TRACE STIMULUS PAIRING TWO-RESPONSE FORMAT: EFFECTS OF RESPONSE LABELS AND PRIOR PROGRAMMED TRANSITIVITY INDUCTION

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Three experiments identified factors that did and did not enhance the formation of two-node four-member equivalence classes when training and testing were conducted with trials presented in a trace stimulus pairing two-response (SP2R) format. All trials contained two separately presented stimuli. Half of the trials, called within-class trials, contained stimuli from the same class while the other half, called cross class trials, contained stimuli from different classes. On within class trials, making a *YES* response was correct and making a *NO* response was wrong. On cross class trials, making a *NO* response was correct and making a *YES* response was wrong. In Experiment 1, similar intermediate percentages of participants (about 50%) formed classes, regardless of whether the responses were labeled *YES* and *NO* or *SAME* and *DIFF*. Response labeling thus did not influence class formation. Regardless of response labels, failures of class formation were primarily due to failure of class-indicative responding produced by within-class transitivity probes. In Experiment 2, only 50% of participants formed classes without prior training, as in Experiment 1, but 100% of participants formed equivalence classes after the establishment of a generalized transitivity repertoire by use of a programmed transitivity induction protocol. Experiment 3 examined two components of the programmed transitivity induction protocol and found that the exclusion of AC trials had no effect on the percentage of participants who formed equivalence classes, while presenting the stimulus sets in randomized order interfered with equivalence class formation. A further analysis found that a number of stimulus control topographies differentiated between individuals who did and did not form equivalence classes. In general, then, these experiments demonstrate that equivalence classes can be formed reliably when training and testing are conducted in an SP2R format, supporting the view that equivalence class formation can account for the development of conceptual categories in natural settings.

Key words: equivalence classes, trace stimulus-pairing two-response trial format, successive matching trial format, generalized transitivity repertoire, keyboarding, college students

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In complex human behavior, responses often generalize among stimuli that bear no physical resemblance to each other. When this occurs, the stimuli are said to be symbolically related to each other, and this presumed symbolic relation is used to account for the transfer of responding among the stimuli. In other words, the above-mentioned stimuli have become members of an equivalence class, which in turn acts as a function-transfer network for the response in question. The establishment of equivalence classes and the function-transfer property acquired by such classes have been used to account for many complex performances that are indicative of meaning (Sidman, 1971) and syntax (Green, Sigurdardottir, & Saunders, 1991; Lazar, 1977; Lazar & Kotlarchyk, 1986; Mackay & Fields, in press), among other things. Equivalence class formation, then, has come to carry a significant explanatory burden in behavior analytic accounts of complex human behavior (Critchfield & Fienup, 2008; Dymond & Rehfeldt, 2000; Hayes, Barnes-Holmes, & Roche, 2001; Leslie, 2002; Mackay & Fields, in press; Sidman, 1994, 2000; Tonneau, 2001).

In real world settings, equivalence classes would have to be formed by most people in a wide variety of training and testing formats and classes would necessarily vary in size and nodal structure (Fields & Verhave, 1987).

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Thus, laboratory-based demonstrations of equivalence classes that vary in size and structure, that can be formed with the training and testing trials presented in a variety of formats, and that are formed by most participants in a study would strengthen the explanatory strength of an equivalence-based account of complex human behavior.

Typically, equivalence class research has used one format for both training and testing: matching-to-sample (MTS) (Cumming & Berryman, 1965). Unfortunately, since many of these studies have not shown particularly high yields (the percentage of participants in a group who formed classes), the use of MTS procedures, per se, does not ensure reliable equivalence class formation. The reliability of equivalence class formation has been substantially increased by the use of: (a) particular preliminary training strategies (Buffington, Fields, & Adams, 1997; Fields, Varelas, Adams, & Belanich, 1997; Fields, Varelas, Reeve, Belanich, Wadhwa, DeRosse, et al., 2000; Saunders & Spradlin, 1989, 1990, 1993); (b) the programming of training and testing during class formation itself (Adams, Fields, & Verhave, 1993, 1999; Arntzen, 2004; Carr, Wilkinson, Blackman, & McIlvane, 2000; Saunders, Saunders, Kirby, & Spradlin, 1988; Schusterman & Kastak, 1993; Sidman, Kirk, & Wilson-Morris, 1985); (c) the topographies of the responses used to select comparison stimuli (Kato, de Rose, & Falieros, 2008); and (d) the content of the stimuli used as members of the potential equivalence classes (Arntzen, 2004; Randall & Remington, 2006). These strategies, then, have provided format-specific support for an equivalence-based analysis of complex human behavior. Demonstrations of reliable equivalence class formation that use trials presented in a variety of formats can further expand the strength of such an analysis.

In recent years, a number of studies explored the formation of equivalence classes in which training and/or testing were conducted using trial formats other than MTS. One such approach employed training that used trials presented in a respondent-type format (Clayton & Hayes, 2004; Leader, Barnes & Smeets, 1996; Leader & Barnes-Holmes, 2001; Leader, Barnes-Holmes, & Smeets, 2000; Smeets, Leader, & Barnes, 1997), also called a stimulus–stimulus pairing format (Layng & Chase, 2001). Using this procedure, stimulus pairs from the same set were presented without any response required from subjects to either stimulus. In these trials, the presentation of the two stimuli might overlap, as in Pavlovian delayed conditioning. Alternately, there might be a short interstimulus interval between the offset of the first stimulus and the onset of the second stimulus, as in Pavlovian trace conditioning.

Using respondent type training, researchers have trained participants to form two 3-member classes (A1–B1–C1 and A2–B2–C2) by the establishment of AB and BC relations, with the presentation of A1 followed by B1, B1 followed by C1, A2 followed by B2, and B2 followed by C2. Tests for class formation, however, were measured in an MTS format; differential responding to the stimuli on emergent relations probes were used to document the formation of the equivalence classes.

Respondent type training has resulted in a wide variation in yields (20 to 100%). Based on relatively small groups (3 through 8 participants), however, the reliability of these yields is questionable. Regardless, these middling yields provide only a modest increment to the explanatory strength of an equivalence-based account of the establishment of complex human behavior (see Tonneau, 2001 for additional comment). In addition, the variability of these empirical outcomes implies that relatively little is known about the parameters needed to establish equivalence classes reliably with respondent type training.

Another format, referred to here as the stimulus pairing two-response or SP2R format, has also been used to establish equivalence classes. SP2R trials differ from respondent type trials in several ways. Trials can contain pairs of stimuli from either the same potential class, called within-class trials, or different potential classes, called cross-class trials. In addition, SP2R trials require a participant to make one response for within-class trials (e.g., *YES*) and another response for cross-class trials (e.g., *NO*). To illustrate, two 3-member classes (A1–B1–C1 and A2–B2–C2) could be established by training the baseline relations (AB and BC) using within-class trials (A1 → B1, B1 → C1, A2 → B2, and B2 → C2) and cross-class trials (A1 → B2, A2 → B1, B1 → C2 and B2 → C1). Because this procedure establishes different responses to within- and cross-class relations, the same procedure can be used to track the emergence of derived relations. For example, after training AB and BC, the emergence of the CA equivalence relations can be assessed with the within-class trials C1 → A1 and C2 → A2 and the cross-class trials C1 → A2 and C2 → A1. The evocation of the *YES* response by the within-class probes and the *NO* response by the cross-class probes would document the emergence of the CA equivalence relation. Similar outcomes obtained with all emergent probes would document the formation of two ABC equivalence classes.

The two responses mentioned above could be denoted with labels other than *YES* and *NO*, such as *SAME/DIFFERENT* or *RELATED/UNRELATED*, with arbitrary symbols, or with manipulanda that are identical in appearance but differ with regard to position. Another variation would be a go/no-go contingency in which a response must occur within a certain time during one type of trial while the same response must not occur during the other type of trial (Frank & Wasserman, 2005; Urcuioli, 2008). In yet a third variation, called a blank-comparison procedure, two stimuli are presented as sample and comparison along with one other stimulus that is called the blank comparison (Costa, Wilkinson, & das Graças de Souza, 2001; Serna, Wilkinson, & McIlvane, 1998; Wilkinson & McIlvane, 1997). If the two stimuli are from the same class, the correct response is pressing the class-based comparison stimulus. If the two stimuli are from different classes, the correct response is pressing the blank comparison stimulus. Because the variations in these procedures reside in the two response options, we refer to all of them generically as SP2R procedures. Elsewhere, the SP2R format has also been referred to as a successive matching-to-sample procedure (Frank & Wasserman, 2005; Urcuioli, 2008), and the precursor to the relational evaluation procedure (pREP) (Cullinan, Barnes, & Smeets, 1998).

The use of SP2R procedures has resulted in a wide variation in yield, raising questions about the parameters needed to induce equivalence classes reliably (Cullinan, Barnes-Holmes & Smeets, 2001; Fields, Reeve, Varelas, Rosen & Belanich, 1997). The following three experiments identified some variables that influenced the reliability of equivalence class formation using trials presented in an SP2R format. Experiment 1 explored the effects of different response labels on the formation of equivalence classes. Experiment 2 explored the effects of a programmed transitivity induction procedure on the subsequent formation of new equivalence classes. Experiment 3 identified two parameters of the programmed transitivity procedure that are responsible for its efficacy. A further detailed analysis identified differences in responding evoked by various baseline relations and emergent relations for participants who did and did not form equivalence classes. It also suggested how the programmed transitivity induction protocol influenced the emergence of these stimulus control repertoires.

EXPERIMENT 1: EFFECT OF RESPONSE LABELS

Cullinan, et al. (2001) reported that the likelihood of class formation under the trace SP2R format was influenced by the labels that denoted the two response options in a trial. In their research, 5 of 5 (100%) participants formed four 3-member equivalence classes when the response options were labeled *SAME* and *DIFF*, but only 2 of 4 (50%) participants did so when the response options were labeled *YES* and *NO*. Using the *YES* and *NO* labels, Fields et al. (1997) similarly found that only 60% of subjects formed equivalence classes under a trace SP2R format. Experiment 1 determined whether the substitution of *SAME/DIFF* response labels for *YES/NO* labels in the procedure used by Fields et al. (1997) would increase the yields in equivalence classes.

Method

Participants

Twenty-six undergraduate students recruited from the Psychology 101 subject pool at Queens College/CUNY participated in the study for partial fulfillment of the course requirement. Participants were randomly assigned to one of two conditions, producing two groups of 13 participants. Each participant had up to 3 hr to complete all training and testing. All participants read and signed informed consent documents before the start of the experiment. Participants had no formal

Table 1

Stimuli in the stimulus sets used as members of equivalence classes (EC) in Experiments 1, 2, and 3, and during Trial Familiarization Training (TFT) in Experiment 1 and Condition 1 of Experiment 2.

Phase	Set #	A	B	C	D
TFT	3	EGGS	BACON	KAV	PUC
	4	STAR	COMET	MOX	SIF
EC	1	LEQ	HUK	POV	BAF
	2	MEV	GUK	ZOJ	YAR

knowledge of equivalence classes and had not participated in any studies of equivalence class formation.

Apparatus

This experiment was conducted on an IBM-compatible microcomputer attached to a 38.1 cm monitor and a standard keyboard. The training and testing procedures were controlled with custom software that programmed all stimulus presentations and recorded all responses. The stimuli were presented in 5-cm × 5-cm square areas on the computer. The vertical positioning of the stimuli is described below. The stimuli used in this experiment are set forth in Table 1. In the symbolic designations, the lower case *w* and *n* designate the stimuli as words (i.e., *w*) or nonsense syllables (i.e., *n*). The members of the stimulus sets used in probing for the formation of equivalence classes were the nonsense syllables *LEQ, HUK, POV,* and *BAF,* which corresponded to the A1n, B1n, C1n, and D1n stimuli, respectively, and *MEV, GUQ, ZOJ,* and *YAR,* which corresponded to the A2n, B2n, C2n, and D2n stimuli, respectively. Stimulus sets 3 and 4 were used during trial familiarization training. Set 3 contained the words *Eggs* (A3w) and *Bacon* (B3w) and the nonsense syllables *KAV* (C3n) and *PUC* (D3n), and set 4 contained the words *Star* (A4w) and *Comet* (B4w) and the nonsense syllables *MOX* (C4n) and *SIF* (D4n).

Procedure

Experimental design. Experiment 1 was a group design that determined whether the labels that designated the two responses in SP2R trials influenced the percentage of participants in a group who formed equivalence classes. In Condition I, the 1 and 2 keys were covered with tabs on which were printed *YES* and *NO,* respectively. In Condition II, the 1 and 2 keys were covered with tabs on which were printed *SAME* and *DIFF,* respectively. Although the following procedures are described with the *YES/NO* response options, the procedures described were used with both conditions.

SP2R trials: content and feedback. Each phase of the experiment that used an SP2R format contained within- and cross-class trials. When feedback was provided, a correct response was followed by the presentation of the feedback message *RIGHT* and an incorrect response was followed by the presentation of *WRONG.* In trials that were not scheduled to provide informative feedback, *—E—* was presented, which indicated the end of the trial.

Temporal and positional parameters of stimuli in SP2R trials. The SP2R trials were presented in different temporal and positional configurations in various phases of the experiment. The first and second stimuli are referred to as the sample and comparison, respectively. The stimuli were horizontally centered on the computer screen while their vertical positioning varied with the trial format. When trials were presented in a delayed SP2R format, the sample was displayed above the comparison with the bottom edge of the sample stimulus 3 cm above the upper edge of the comparison stimulus. A trial began with the presentation of a sample stimulus. After making an observing response (one press of the spacebar), a comparison stimulus was displayed, and both stimuli remained on the screen until the participant pressed the 1 or 2 key. Either response terminated both stimuli and resulted in the presentation of the feedback stimulus, as described above.

When trials were presented in a trace SP2R format, the observing response terminated the sample stimulus and, following a 0.1-s interval, the comparison was then displayed and remained on until the subject pressed the 1 or 2 key. In some phases that used the trace SP2R format, the comparison was presented below the sample, as in a delayed SP2R trial. In other phases, the comparison was presented in the same location as the sample stimulus. The temporal and positional parameters of the trace SP2R trials were the same as those used in the successive matching-to-sample trials described by Frank and Wasserman (2005).

Block structure, mastery criteria, and feedback. Every stage of the experiment was divided into phases. Each phase contained a block of trials that served a particular behavioral function or combination of functions. The trials in a block were presented in a random order without replacement. Both training and derived relations test blocks were repeated until all of the trials in a block produced 100% accurate responding (mastery) or for a given number of repetitions. The blocks used to establish new conditional discriminations were conducted with all trials in a block producing informative feedback. Once mastery was achieved, the relations were maintained in blocks where informative feedback was presented for a decreasing percentage of trials in a block. Typically, feedback was reduced from 100% to 75% to 25% to 0% in successive blocks as long as the mastery level of responding was maintained. If mastery was not achieved at a given level of feedback, the participant was reexposed to the feedback percentage at the prior, higher level, and then again provided with the feedback percentage used in the previously failed block. This back-up procedure was repeated until mastery was achieved at all levels of feedback. This feedback reduction and back-up procedure is referred to hereafter collectively as Standard Feedback Reduction.

Trial familiarization training. The experiment began with trial familiarization training, which was designed to teach participants how to respond to each of the stimuli presented in a trial. In addition, it was designed to establish conditional discriminative control while systematically shifting the parameters of a trial from a delayed SP2R format to a trace SP2R format with all stimuli presented in the same location.

The 10 phases of trial familiarization training are set forth in Appendix A. In all phases, trials were presented in the SP2R format. Phases 1–5 used the A and B stimuli in sets 3 (*EGGS* and *BACON*) and 4 (*STAR* and *COMET*), respectively. The stimuli in each set were semantically related to each other to maximize the establishment of conditional discriminations. Symbolically, training was conducted with Aw → Bw relations. In Phases 1–3, the sample and comparison stimuli were presented in a delayed format with the sample appearing above the comparison. These three phases contained varying levels of prompts to maximize the production of correct responding. In Phase 1, full prompts were given, so that the prompt ''*study cue press spacebar*'' was presented below the sample stimuli and the prompt ''*press Yes or No*'' was presented below the comparison stimuli. In Phase 2, partial prompts were used; ''*study and press*'' was presented beneath each sample stimulus and ''*Yes No*'' was presented beneath each comparison stimulus. In Phase 3 and all subsequent phases, no prompts were provided. The mastery level of responding in Phase 3 demonstrated that responding was under the conditional discriminative control of the sample and comparison stimuli.

In Phase 4, the sample and comparison stimuli were presented in a trace mode, with the comparison stimulus still displayed below the sample. Phase 5 was identical to Phase 4 except that the comparison stimuli were now presented in the same position as the sample stimuli. Phase 6 was identical to Phase 5, except that the comparison stimuli (which had been B1w and B2w) were now replaced with C stimuli (which were nonsense syllables, denoted as Cn). Symbolically, training was conducted with Aw → Cn relations. Phase 7 was identical to Phase 6, except that the words that had been used as the sample stimuli (Aw) were now also replaced with nonsense syllables (Dn). Symbolically, training was conducted with Dn → Cn relations. Phases 1 through 7 all provided participants with 100% feedback. Phases 8–10 were identical to Phase 7 except that the percentage of trials in a block that occasioned feedback was systematically reduced using the Standard Feedback Reduction procedure outlined previously.

To summarize, trial familiarization training was designed to transfer control exerted by semantically related stimuli (Aw → Bw) presented in a delayed stimulus pairing format to control exerted by conditional relations between meaningful and arbitrary stimuli (Aw → Cn) and two arbitrary stimuli (Dn → Cn), both of which were presented in a trace stimulus pairing format. In addition, trial familiarization training also induced maintenance of these relations in the absence of informative feedback. Although successful training established linked conditional discriminations that yielded the training structure Dn → Cn ← Aw → Bw, no probes were presented to evaluate the emergence of any relations that could be derived from the stimuli in these sets.

Equivalence class formation. At the completion of trial familiarization training, participants attempted to form new equivalence classes. Trials were presented in a trace SP2R format with samples and comparisons in the same location. As listed in Appendix B, the procedure began with the establishment of AB conditional discriminations by the presentation of both within-class and cross-class trials with 100% informative feedback. Acquisition of the AB relations was complete when responding reached 100% accuracy. Once acquired, the block of AB trials was repeated but the percentage of trials in a block that produced informative feedback was reduced using the Standard Feedback Reduction procedure. Once the AB conditional discriminations were maintained in the absence of informative feedback, the symmetrical relation between A and B was evaluated with the presentation of B1 → A1 and B2 → A2 within-class probes, along with the B2 → A1 and B1 → A2 cross-class probes. All of these probes, as well as all subsequently presented emergent relations probe trials, were presented with no informative feedback. Next, trials were presented to establish the BC conditional discriminations, again using the Standard Feedback Reduction procedure. Thereafter, the symmetrical property of the B and C stimuli was assessed with CB symmetry probes. After passing the CB test, subjects were presented with a block of trials that contained a combination of within- and cross-class AB, BC, BA, and CB trials. Class-consistent responding in this test block confirmed the maintenance of all relations when presented together.

Having established the necessary baseline relations, participants were then presented with blocks containing probes to assess the emergence of the various derived relations. Each of these blocks was presented with no informative feedback. Participants were first probed for the emergence of transitivity through the presentation of the within-class and cross-class AC probes. Next, the emergence of equivalence relations was assessed with the presentation of within-class and cross-class CA probes. Although the formation of 3-member classes would be documented by mastery levels of responding in all of the probes mentioned above, these derived relations were assessed in isolation. The next block examined whether class indicative responding would be maintained if all possible within- and cross-class trials were presented in randomized order within a single block, which was called the 3MIX test block. This block was repeated up to three times or until performance reached the mastery criterion. Mastery level responding during the 3MIX test block confirmed the formation of two 3-member classes.

After participants passed the 3MIX test, the 3-member classes were expanded to two 2-node 4-member classes by training CD and then maintaining CD during Standard Feedback Reduction. Expansion of class size was tested through the presentation of a 4MIX test block that contained all possible baseline, symmetry, transitivity, and equivalence probes. Symmetry was evaluated using the within-class and cross-class DC probes. The emergence of one-node transitive relations was assessed with within-class and cross-class BD probes. The emergence of the two-node equivalence relations was assessed with within-class and cross-class DA probes.

Generalization to delayed matching-to-sample. The last phase of the experiment evaluated the maintenance of the four-member equivalence classes with a single test block that contained trials presented in a two-choice delayed matching to sample (DMTS) format. This test block was preceded by the presentation of the following instructions:

> PLEASE DO NOT TOUCH ANY KEYS ON THE KEYBOARD YET. In this part of the experiment, many new trials will be presented. Each trial will now contain THREE nonsense words you've seen before. First, ONE will appear at the TOP of the screen, then TWO will appear at the bottom. Your task is to select the BOTTOM word that goes with the TOP word. Initial trials will also include instructions that tell you which keys to press. These instructions will eventually disappear. Thank you for your cooperation!

The test block itself contained all of the baseline conditional discriminations and the emergent relations probes. As illustrated in Appendix C, each relation was presented on two trials. All trials began with a sample stimulus from one of the two classes. An observing response resulted in its termination, followed in 0.1 s with the concurrent presentation of a pair of comparison stimuli, one from each class. For a given pair of comparisons, their left and right positions were balanced across trials. Both comparisons were displayed until one was selected by pressing the 1 or 2 key to choose the comparison on the left or right, respectively. Selection of a comparison resulted in the presentation of the – *E* – message. Mastery in this test block (at least 94% of trials evoking class-consistent comparison selection) indicated the maintenance of the two equivalence classes and generalization to a new trial format.

Results and Discussion

Effect of response labels. Figure 1 illustrates the number of participants who began and completed each stage of the experiment. Shortly after the experiment began, 3 participants dropped out of the experiment leaving 13 in the *SAME/DIFF* group and 10 in the *YES/NO* group. Two 3-member equivalence classes were formed by 6 of 13 (46%) participants in the *SAME/DIFF* condition and 7 of 10 (70%) participants in the *YES/NO* condition, a difference that was not significant (Fisher's exact test, $p = .40$). When all participants were considered, three-member equivalence classes were formed by 6 of the 13 (46%) and by 7 of the 13 (54%) participants who began the experiment in the *SAME/DIFF* and *YES/NO* conditions, respectively. Once again this difference was not significant (Fisher's exact test, $p = .70$). Regardless of metric, the differences in the effects of the response labels did not influence likelihood of forming three-member equivalence classes. For participants in both groups, if the three-member classes were formed, class size inevitably expanded to four members. Those participants who continued on then demonstrated class indicative performances in the final DMTS test.

Cullinan et al. (2001) reported that the likelihood of equivalence class formation was much greater when responses were labeled *SAME* and *DIFFERENT* (4 of 4) instead of *YES* and *NO* (0 of 4). These results were not replicated in the present experiment, nor did response labels influence class expansion or maintenance of class indicative performances in different trial format. Rather, both sets of response labels produced similar and moderate yields, which also were similar to those reported by Fields et al. (1997). These results

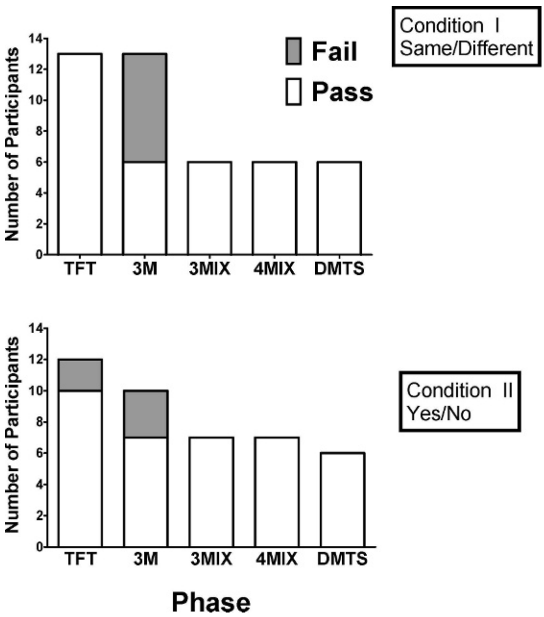

Fig. 1. Number of participants in the *YES/NO* and *SAME/DIFF* groups (Conditions I and II) in Experiment 1 who began each condition (total height of each bar), who completed each condition (white portion of each bar), and who did not complete each phase of the condition (gray portion of each bar). The phases used in each condition were preliminary training (TFT), three-member class formation (3M), maintenance of three-member classes (3MIX), expansion of class size from three to four members (4MIX), and maintenance during a delayed matching-to-sample test (DMTS). When the height of a bar to the right of an adjacent bar is lower than the adjacent bar, the difference is due to subjects dropping out of the experiment between conditions.

demonstrate that the high yield produced using the *SAME/DIFFERENT* response labels, as reported by Cullinan et al. (2001), was discriminatively or contextually limited to the presence of some factors in their experiment that were absent in the present experiment. The identification of the variables responsible for making class formation differentially sensitive to response labels will await outcome of future research.

Effect of instructions on class maintenance in DMTS tests. As noted above, all participants who formed three-member classes successfully expanded the classes to four members. Finally, class indicative responding generalized immediately and with no training to relations in the four-member classes that were presented in two-choice DMTS format. As noted in the Method section, the instructions for the DMTS transfer test were minimal. Thus, the virtually instantaneous generalization of class-indicative performances to DMTS trials attests to the format independence of the baseline relations that were trained and the derived relations that had emerged in the trace SP2R format.

Transitivity and failure of equivalence class formation. For the 6 of 10 participants who did not form the equivalence classes, the failures were largely due to performances evoked by the transitivity probes. Although participants correctly made the *NO* response when presented with the cross-class A1–C2 and A2–C1 probes, they also made the same *NO* response when presented with the within-class A1–C1 and A2–C2 probes. This finding replicated that reported by Fields et al. (1997). By implication, then, the prior induction of a transitivity repertoire that would be active during class formation ought to increase the likelihood of class formation. This notion is addressed in the remaining sections of this article.

EXPERIMENT 2: EFFECT OF PROGRAMMED TRANSITIVITY INDUCTION

Experiment 2 determined whether the prior induction of a generalized transitivity repertoire would increase the likelihood of equivalence class formation. Condition I of Experiment 2 replicated the procedures used in Experiment 1, where a minimal form of preliminary training preceded an attempt to establish equivalence classes using trials presented in the trace SP2R format. Condition II, by contrast, began with a highly programmed preliminary training procedure designed to induce a generalized transitivity repertoire, after which participants attempted to establish new equivalence classes, as in Condition I. Greater yields in Condition II than I would indicate that the prior induction of a generalized transitivity repertoire enabled individuals to form new equivalence classes.

Method

Participants

Thirty undergraduate students were recruited, from the same subject pool and meeting the same requirements as those in Experiment 1, and were randomly assigned to one of two conditions, producing two groups of 15 participants. Unexpected dropouts between recruitment and participation in Experiment 2 resulted in 15 and 11 participants in Conditions I and II, respectively. Each participant had up to 3 hr to complete all training and testing.

Table 2

Stimuli used in the Programmed Transitivity Induction (PTI) Protocol in Condition II of Experiment 2 and all conditions of Experiment 3.

Set	A	B	C	D	E	F
3	EGGS	BACON	TOAST			
4	STAR	COMET	MOON			
5	LION	TIGER	STRIPE	HUV	BON	BEW
6	MILK	COOKIE	OVEN	HET	ZIS	MAR
7	GAZ	NOS	ZOX			
8	WAP	RUP	JUS			
9	VIN	BER	SOL			
10	PEX	YUT	MOS			

Apparatus

The hardware and software were the same as those used in Experiment 1. The stimulus sets used in Experiment 2 are listed in Table 2. As in Experiment 1, stimulus sets 1 and 2 were used in the equivalence class probes for both conditions. Stimulus sets 3 through 10 were used during programmed transitivity induction. Sets 3 and 4 contained three semantically related English words. Sets 5 and 6 each contained three words and three nonsense syllables. Sets 7 through 10 each consisted of three nonsense syllables. The stimuli in sets 5 through 8 in the present experiment were not used in Experiment 1.

Procedure

Preliminary training: Condition I. The participants in Condition I began the experiment with the same trial familiarization training procedure used in Experiment 1.

Preliminary training: Condition II. Condition II began with exposure to the programmed transitivity induction (PTI) protocol. It consisted of an amalgam of procedures, each of which was known to facilitate the formation of a variety of stimulus control topographies. These were (a) training with many stimulus sets (Dymond, Roche, Forsyth, Whalen, & Rhoden, 2008; Fields & Reeve, 2001; Fields, Reeve, Matneja, Varelas, Belanich, Fitzer, et al., 2002; Fields et al., 2000; Schusterman & Kastak, 1993; Varelas, 2002; Wright, Cook, Rivera, Sands, & Delius (1988); (b) the gradual changing of the stimuli across sets, which has been dubbed stimulus programming (Zygmont, Lazar, Dube, & McIlvane, 1992); (c) trial-unique training consisting of the presentation of transitivity probes with direct reinforcement instead of testing under extinction conditions (Wright et al., 1988); and (d) the establishment of a network of multinodal stimulus relations (Fields & Verhave, 1987; Kato et al., 2008).

Appendix D shows each phase of the programmed transitivity protocol. Phases 1 through 6 involved a trial-unique procedure in which all relations were directly trained through the presentation of informative feedback on all trials. All phases involved the presentation of a block of training trials that was repeated until no more than one error occurred in a block (the mastery level of responding).

Phase 1 trained participants to respond appropriately to the stimuli presented in each trial. This phase used stimulus sets 3 and 4. To maximize acquisition, the three stimuli in each set contained words that were all semantically related to each other: A to B, B to C, and A to C. Set 3 consisted of *Eggs* (A3w), *Bacon* (B3w), and *Toast* (C3w). Set 4 consisted of *Star* (A4w), *Comet* (B4w), and *Moon* (C4w). After training *Eggs* → *Bacon* (A3w → B3w) and *Star* → *Comet* (A4w → B4w), training continued with *Bacon* → *Toast* (B3w → C3w) and *Comet* → *Moon* (B4w → C4w). Then the transitive relations *Eggs* → *Toast* (A3w → C3w) and *Star* → *Moon* (A4w → C4w) were directly trained in a block that also contained the prerequisite AB and BC relations. Phases 2 through 5 established a generalized transitivity repertoire with a new set of stimuli: those in sets 5 and 6. Each stimulus set contained six stimuli – three words and three nonsense syllables – but only three stimuli from each set were used in any given phase. As each phase was mastered, the next phase contained trials that incorporated only one change in the parameters that defined the new phase.

In Phase 2, the stimulus sets contained three common English words. Set 5 contained *Lion* (A5w), *Tiger* (B5w), and *Stripe* (C5w), and Set 6 contained *Milk* (A6w), *Cookie* (B6w), and *Oven* (C6w). In each set, a semantic relation existed between the first and second word, and between the second and third word, but not between the first and third word. After acquiring *Lion* → *Tiger* (A5w → B5w), *Milk* → *Cookie* (A6w → B6w), *Tiger* → *Stripe* (B5w → C5w), and *Cookie* → *Oven* (B6w → C6w), participants were given transitivity training with *Lion* → *Stripe* (A5w → C5w) and *Milk* → *Oven* (A6w → C6w).

Phase 3 used two previously used words from each set and one new stimulus that was a nonsense syllable. Thus, one set contained *Lion* (A5w), *Tiger* (B5w), and *HUV* (D5n) and the other contained *Milk* (A6w), *Cookie* (B6w), and *HET* (D6n). After training the new conditional discriminations *Tiger* → *HUV* (B5w → D5n) and *Cookie* → *HET* (B6w → D6n), participants were given *Lion* → *HUV* (A5w → D5n) and *Milk* → *HET* (A6w → D6n) training, a transitive relation between a word and a nonsense syllable.

Phase 4 used one of the previously used words, the previously used nonsense syllable, and a new nonsense syllable. Thus, the stimuli in one set were *Lion* (A5w), *HUV* (D5n), and *BON* (E5n), and in the other set were *Milk* (A6w), *HET* (D6n), and *ZIS* (E6n). Training continued with *Lion* → *HUV* (A5w → D5n) and *Milk* → *HET* (A6w → D6n), while also establishing the new conditional discriminations *HUV* → *BON* (D5n → E5n) and *HET* → *ZIS* (D6n → E6n), the first conditional discriminations between two nonsense syllables. Once mastered, participants were presented with *Lion* → *BON* (A5w → E5n) and *Milk* → *ZIS* (A6n → E6n), each a potential transitive relation between a word and a nonsense syllable.

Phase 5 used the two previously used nonsense syllables from each set and added a new nonsense syllable. The stimuli in one set were *HUV* (D5n), *BON* (E5n), and *BEW* (F5n), and in the other set were *HET* (D6n), *ZIS* (E6n), and *MAR* (F6n). Training continued with *HUV* → *BON* (D5n → E5n) and *HET* → *ZIS* (D6n-E6n), while establishing the new conditional discriminations *BON* → *BEW* (E5n → F5n) and *ZIS* → *MAR* (E6n → F6n), which were additional conditional discriminations between two nonsense syllables. Thereafter, participants were presented with *HUV* → *BEW* (D5n → F5n) and *HET* → *MAR* (D6n → F6n), the second potential transitive relation that consisted of two nonsense syllables. To summarize, Phases 2 through 5 established sets of six stimuli that were linked by training and could induce the four transitive relations Aw → Cw, Aw →Dn, Aw → En, and Dn → Fn.

Phase 6 used the new stimuli in sets 7 and 8. Each set contained three nonsense syllables: *GAZ* (A7n), *NOS* (B7n), and *ZOX* (C7n) in one and *WAP* (A8n), *RUP* (B8n), and *JUS* (C8n) in the other. After training the relations *GAZ* → *NOS* (A7n → B7n) and *WAP* → *RUP* (A8n → B8n), the procedure continued with the training of *NOS* → *ZOX* (B7n → C7n) and *RUP* → *JUS* (B8n → C8n). Finally, training was conducted for the two potential transitive relations, *GAZ* → *ZOX* (A7n → C7n) and *WAP* → *JUS (A8n* → *C8n)*. These were the fifth potential transitive relations and were also the second pair of potential transitive relations that consisted of two nonsense syllables. The immediate emergence of transitivity in Phases 2–6 was demonstrated by responding that was at least 88% accurate during the first block in a phase that contained the trials in a potential transitive relation.

Phases 7 through 9 used two new stimulus sets, each containing three nonsense syllables. Set 9 contained *VIN* (A9n), *BER* (B9n), and *SOL* (C9n), while set 10 contained *PEX* (A10n), *YUT* (B10n), and *MOS* (C10n) for the other. Except where otherwise noted, all trials produced informative feedback.

Phase 7 began with a block that trained the AB relations, which was repeated until no more than one trial in the block evoked an incorrect response (mastery). The next block trained the BC relations but also included AB trials, which again was repeated until mastery was achieved. Thereafter, the block containing AB and BC trials was repeated, this time using the Standard Feedback Reduction procedure described in Experiment 1. The next block presented contained the four AB and four BC trials along with eight AC trials. Informative feedback was not presented for any of the trials in this block, which assessed the emergence of the transitive relations, AC. If more than one trial in this block evoked an incorrect response, the block was repeated with all trials producing informative feedback until the mastery level of responding was produced by the trials in the block. Mastery of this block, with or without feedback, resulted in advancement to the next phase of programmed transitivity induction.

Phase 8 was identical to Phase 7, except that the sample and comparison stimuli, which until now had been presented using a delay format, were now presented in a trace format with the sample and comparisons presented in different locations.

Phase 9 was identical to Phase 8, except that the two stimuli in a trial were displayed in the same location. Mastery of Phase 9 signaled completion of the programmed transitivity induction procedure, at which point participants were placed into the equivalence class formation portion of the experiment, which was identical to the equivalence class formation probe used in Experiment 1.

Results and Discussion

Trial familiarization training. All participants in Condition I completed trial familiarization training.

Programmed transitivity induction. All participants in Condition II completed the programmed transitivity induction protocol. The emergence of transitive relations was measured with the performances evoked by the blocks that contained transitivity trials. These data are presented in Table 3, where different columns present the data for the AC relations in Phase 1, the AC, AD, BD, and DF relations in Phases 2–5, and the AC relations in Phases 6 and 7. Data for individual participants were presented in sets of rows separated by a blank row. The successive rows indicate repetition of the same block, until mastery. Each cell indicates the number of blocks needed to respond correctly on at least seven of the eight trials in a block. The immediate emergence of a transitive relation was demonstrated by responding correctly on at least seven of the eight trials in the first presentation of a block for a given transitivity probe.

In Phase 1, all of the potential transitive relations produced correct responding in the first block. Since the stimuli in these sets were all semantically related to each other prior to the start of the experiment, these performances did not document the emergence of transitive relations.

In Phases 2 through 7, up to six different transitive relations could emerge: four in Phases 2 through 5 (Aw → Cw, Aw → Dn, Aw → En, and Dn → Fn), one in Phase 6 (An → Cn), and one in Phase 7 (An → Cn). Transitive relations were demonstrated in all six cases by

Table 3

Percent of correct trials in each transitive relation test block in each phase of the in programmed transitivity induction protocol used in Condition 2 of Experiment 2. Each column is for a separate phase. The transitive relation in the phase is indicated in a letter-letter format. The shaded cells contain data that can indicate the emergence of transitive relations. Cells that contain numbers followed with an 'a' were conducted with uninformative feedback. Cells with numerals not followed with an 'a' were shown with informative feedback. Cellular entries in bold font indicate emergent transitive relations. Cellular entries in normal font do not indicate the emergence of transitive relations. See text for more information.

Phase Nos.	>>>	1	2	3	4	5	6	7	8	9
Stim-Sets	>>>	3&4	5&6				7&8	9&10		
Transitive Rel.	>>>	AC	AC	AD	BE	DF	AC	AC	AC	AC
Subject	Blk	% correct per block for "transitive" relations								
44	1	100	**88**	**100**	**100**	**100**	**100**	**100a**	**100a**	**100a**
50	1	100	**88**	**100**	**100**	**100**	**100**	**100a**	**100a**	**100a**
43	1	100	**88**	**88**	**100**	**100**	**100**	**100a**	**100a**	**100a**
49	1	100	**88**	**100**	**100**	**88**	**100**	**94a**	**100a**	**100a**
51	1	100	**88**	**88**	**100**	**88**	**88**	**100a**	**94a**	**100a**
48	1	100	**75**	**88**	**100**	**100**	**100**	**100a**	**100a**	**100a**
	2		100							
47	1	100	**88**	**100**	**100**	**88**	**100**	**75a**	**94a**	**100a**
								100		
46	1	100	**88**	**75**	**100**	**100**	**88**	**56a**	**94a**	**81a**
	2			100				88		88
	3							100		88
										94
52	1	100	**100**	**100**	**100**	**100**	**63**	**69a**	**88a**	**100a**
	2						75	69	100	
	3						100	63		
	4							75		
								94		
53	1	100	**75**	**88**	**100**	**100**	**50**	**75a**	**88a**	**100a**
	2		100				88	69	94	
	3							75		
	4							75		
	5							81		
	6							63		
	7							75		
	8							75		
								100		
45	1	100	**63**	**100**	**100**	**100**	**25**	**75a**	**94a**	**100a**
	2		100				63	75		
	3						63	94		
	4						63			
	5						50			
	6						100			

5 participants (44, 50, 43, 49, and 51), in five cases by 2 participants (48 and 47), in four cases by 3 participants (46, 45, 52), and in three cases by 1 participant (53). For all 11 participants, then, transitive relations were demonstrated in at least three of the probes.

A generalized transitivity repertoire is demonstrated when transitive performances are immediately evoked by many different transitivity probes. Condition II provided 66 opportunities to evaluate transitive relations (6 cases × 11 participants). Immediate emergence was demonstrated in 54 of the 66 cases. Thus, the programmed transitivity induction protocol induced generalized transitivity repertoires. In the remaining 12 cases, the ''transitive'' relations did not emerge in the first block but rather were directly trained.

The stimuli used in Phase 7 were also used in Phases 8 and 9. Thus, performances in the latter phases did not assess the emergence of transitive relations. Instead, they evaluated the effects of format changes on the maintenance of previously emergent or trained relational responding. Transitivity-indicative responding was maintained with a change from a delay to a trace SP2R format with stimuli presented in different locations, and then with a change of comparison location with trials presented in the trace SP2R format. These performances, then, documented the stability of the transitive relations when challenged with a number of changes in trial format.

Likelihood of equivalence class formation. The top panel of Figure 2 illustrates the likelihood of equivalence class formation following trial familiarization training in Condition I. All 15 participants completed trial familiarization training. Seven participants did not form classes: As in Experiment 1, virtually all of the within- and cross-class AC trials evoked the *NO* response. The 8 remaining participants formed three-member equivalence classes, maintained class-indicative responding during the 3MIX test, expanded class size from three to four members, and maintained class-indicative responding during the DMTS test.

The bottom panel of Figure 2 illustrates the likelihood of equivalence class formation after the completion of programmed transitivity induction in Condition II. All 11 participants who began PTI formed generalized transitivity repertoires. After the completion of PTI, 2 participants dropped out. The 9 remaining

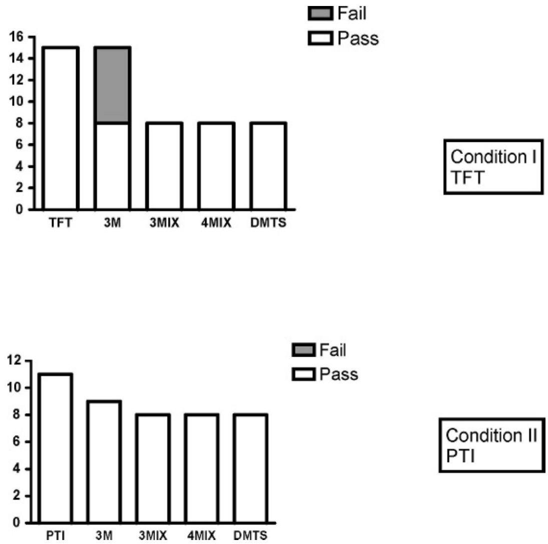

Fig. 2. Number of participants in Conditions I and II of Experiment 2 who began each condition (total height of each bar), who completed each phase (white portion of each bar), and did not complete each condition (gray portion of each bar). The phases of the experiment in each condition were preliminary training (TFT for Condition I and Programmed Transitivity Induction (PTI) for Condition II), three-member class formation (3M), maintenance of three-member classes (3MIX), expansion of class size from three to four members (4MIX), and maintenance during a delayed matching-to-sample test (DMTS). When the height of a bar to the right of an adjacent bar is lower than the adjacent bar, the difference is due to subjects dropping out of the experiment between conditions.

participants then formed three-member equivalence classes, after which 1 participant dropped out. The remaining 8 participants then showed the expansion of class size from three to four members, and the maintenance of the classes during the DMTS test.

A comparison of the data in the upper and lower panels of Figure 2 illustrates the effects of PTI on the subsequent formation of new equivalence classes. Two 3-member equivalence classes were formed by 53% of participants after trial familiarization training and by 100% of participants after PTI. The likelihood of this difference in yield occurring by chance is .02 (Fisher Exact test). Therefore, the induction of a generalized transitivity repertoire by the PTI procedure enhanced equivalence formation when training and testing were conducted in a trace SP2R format.

For both groups, all participants who formed three-member classes and remained in the experiment expanded class size from three to four members and maintained class indicative responding during the DMTS test. Thus, while the programmed transitivity induction influenced the formation of the initial three-member equivalence classes it did not influence the expansion of class size or the maintenance of the expanded classes when tested with an alternate trial format.

EXPERIMENT 3: COMPONENT EFFECTS OF PROGRAMMED TRANSITIVITY INDUCTION

Experiment 2 demonstrated the efficacy of the PTI protocol. Because the PTI protocol is rather complex, its efficacy could be attributed to any of the procedural components in the protocol. Experiment 3 was designed to identify how the enhancement of equivalence class formation was influenced by two of the components of the PTI procedure. One component entailed training with stimulus sets that were introduced in a progression that varied systematically from sets of three semantically-related words to sets of three nonsense syllables. Another component involved the direct training of potential transitive relations in each phase of the protocol. Experiment 3 explored the effects of each of these components.

Experiment 3 consisted of three experimental conditions. In Condition I, participants were exposed to a streamlined version of the PTI protocol, which included both the systematic ordering of stimulus sets and the direct training of transitive relations. In Condition II, participants were exposed to the same streamlined version of the PTI procedure except that this version did not include, and thus did not directly train, the transitive relations. In Condition III, participants were exposed to the same streamlined version of the PTI procedure used in Condition I, except the ordering of the stimulus sets was random instead of being systematic. After each form of preliminary training, all participants attempted to form equivalence classes, using the same procedure that was used in Experiments 1 and 2. Differences in the likelihood of forming equivalence classes were used to determine the effect of the variables that distinguished the protocols in Conditions I and II, and I and III. Finally, the programmed transitivity induction protocol used in Experiment 2 had a number of procedural redundancies that may not have influenced its efficacy. In Experiment 3, those redundancies were eliminated. A comparison of yields across Experiments 2 and 3 would determine the impact of the removed components on the efficacy of the programmed transitivity induction protocol.

METHOD

Subjects

Twenty-two undergraduate students from the same subject pool and meeting the same requirements as those in Experiment 1 were recruited and randomly assigned to one of three different conditions. Each participant had up to 3 hr to complete all training and testing.

Apparatus

The hardware and software were identical to those used in the prior experiments.

Stimuli

As in the previous experiments, this experiment used both words and nonsense syllables as stimuli. The stimulus sets used in Experiment 3 are in Table 2 and correspond to the stimulus sets used in Condition II of Experiment 2. As in Experiments 1 and 2, stimulus sets 1 and 2 were used in the equivalence class probes for all conditions. As in Experiment 2, stimulus sets 3 through 10 were used during programmed transitivity induction.

Procedure

Experimental design. Each condition began with a different form of the programmed transitivity induction (PTI) procedure used in Condition II of Experiment 2. Once completed, participants in all conditions were exposed to the same follow-up condition, which was identical to that used in Experiment 2: the formation of three-member equivalence classes, testing for the maintenance of the three-member classes, expansion of the three-member classes to four-member equivalence classes, and testing for the maintenance of the classes when using a delayed matching-to-sample transfer procedure.

Condition I. In Condition I, participants were placed in a streamlined version of the programmed transitivity induction procedure that had been used in Condition II of Experiment

Table 4

Analysis of transitivity by phase during preliminary training for participants in Experiment 3, Condition 1. Sub-mastery performances are indicated in bold and italicized font.

		Phase/FB%/Transitive Relation								
		1	2	3	4	5	6	7	8	9
		100	100	100	100	100	100	100	100	75-0
Participant	Block	Aw-Cw	Aw-Cw	Bw-Dn	Cw-En	Dn-Fn	An-Cn	An-Cn	An-Cn	An-Cn
3302	1	100	88	100	100	88	88	100	100	100
3299	1	100	100	100	100	88	100	***71***	100	100
	2							100		
3296	1	100	100	88	100	100	100	100	100	100
3279	1	88	100	100	100	100	100	100	100	100
3295	1	100	100	100	100	***75***	100	100	100	100
	2					100				
3280	1	100	88	100	100	88	***75***	88	100	96
	2						100			
3276	1	88	***75***	100	100	100	***50***	80	96	96
	2		100				88	100		

2. The phases for this condition are set forth in Appendix E. Specifically, Experiment 3 removed the repetition of the Standard Feedback Procedure, used in each of Phases 7 through 9 of Experiment 2, so that participants did not experience feedback reduction until the final stage of PTI. Additionally, because feedback was not reduced during those phases where the positional and temporal parameters of the stimulus presentation were changed, participants only experienced a single procedural change in each phase of PTI in Experiment 3. Phases 1 through 6 were identical to those used in the prior experiment. Phase 7, however, introduced the trace presentation of stimuli in different locations and did not include any feedback reduction procedure such as had been used in Experiment 2. Phase 8 then introduced the trace presentation of stimuli in the same location, again without any feedback reduction such as had been used in Experiment 2. In Phase 9, the temporal and positional changes from Phases 8 and 9 remained, but now were accompanied by the feedback reduction procedure, wherein feedback was decreased using the same Standard Feedback Reduction procedure used in Experiments 2 and 3. The same stimulus sets (9 and 10) were used in each of these phases and were the same as those used in Phases 7 through 9 of the prior experiment.

Condition II. Preliminary training was the same as in Condition I except no AC trials were included in the PTI protocol.

Condition III. In Condition III, participants were presented with an unsystematic version of the streamlined PTI procedure used in Condition I. In Condition III, the stimulus sets were introduced in the randomized sequence illustrated in Appendix F.

Equivalence class formation. Upon completion of the appropriate PTI procedure, or after 90 min if the participant had not completed all the phases of the procedure, all participants were probed for the formation of equivalence classes that used the same procedure and stimulus sets used in the Experiments 1 and 2.

Delayed matching-to-sample transfer test. Upon the successful establishment of the 4-member equivalence classes, subjects were then placed into the DMTS transfer test, which was identical to that used in the prior experiments.

Results and Discussion

Performances during preliminary training. All 7 participants completed the streamlined programmed transitivity induction protocol used in Condition I. Table 4 presents performances evoked by the transitivity trials in each phase of that protocol. Immediate emergence of a transitive relation was demonstrated by responding correctly on at least seven of the eight trials in the first presentation of the block for a given transitivity probe. In Phase 1, all of the potential transitive relations produced correct responding in the first block. In Phases 2 through 7, which contained six different transitive relations, transitive relations were demonstrated in all six cases by 3 participants (3302, 3296, and 3279), in five cases by 3 participants (3299, 3295, and 3280), and in three cases by 1 participant (3276). Thus, all participants demonstrated transitive relations in at least three of the probes. Of the 42 opportunities to evaluate transitive relations (6 blocks × 7 participants), immediate emergence was demonstrated in 36 cases. Thus, the streamlined PTI protocol induced generalized transitivity repertoires for all participants. In general, then, these results are very similar to that obtained in the prior experiment. Analogous data were not analyzed for participants in Condition II because no transitivity probes were included in the protocol, nor in Condition III because only one participant completed preliminary training.

Likelihood of equivalence class formation. Figure 3 illustrates the number of participants who started and completed each phase of the experiment in Conditions I, II, and III. Preliminary training was completed by 100% (7 of 7) participants in Condition I, which utilized the basic PTI procedure that included transitivity probe trials, by 88% (7 of 8) of participants in Condition II, where transitivity probe trials were removed from the protocol, and by 14% (1 of 7) of participants in Condition III, where the phases of the PTI procedure were presented in a randomized order.

Unnecessary components of the PTI protocol. As illustrated in Figure 3, all 7 participants in Condition I formed three-member equivalence classes, expanded class size from three to four members, and demonstrated the maintenance of the equivalence classes when assessed in the DMTS format. These yields were equivalent to those observed in Condition II of Experiment 2. Therefore, the components that were removed from the PTI protocol, namely the repetition of the Standard Feedback Reduction procedure, did not influence the efficacy of the PTI protocol.

Role of transitivity probes. Condition II utilized the PTI protocol that did not include potential transitive relations trials. The 7 participants who completed this form of preliminary training formed three-member equivalence classes and expanded class size to four members. One of the 7 participants was excused due to time constraints. The remaining 6 participants successfully completed the

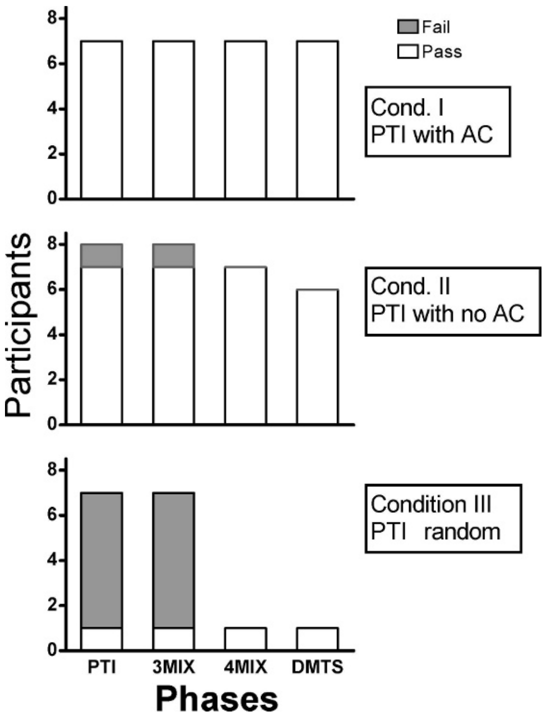

Fig. 3. Figure 3 illustrates the number of participants who started and completed each phase of Experiment 3 in Conditions I, II, and III. The format of this figure is like that used for Figures 1 and 2.

DMTS transfer test. The one participant who did not complete the preliminary training failed to form three-member equivalence classes and was then dismissed. The yields after Conditions I and II were equivalent. Thus, the inclusion of transitive relations trials in the PTI protocol did not influence the efficacy of that protocol.

Ordering of stimulus sets. In Condition III, the systematic progression of stimulus sets was removed from the PTI protocol. Only 1 of the 7 participants in this condition completed preliminary training. Thereafter, that participant formed three-member equivalence classes, expanded class size to four members, and maintained class indicative responding during the DMTS test. The 6 participants in Condition III who did not complete preliminary training also failed to form three-member equivalence classes and were dismissed. The yields in Condition III were much lower than those obtained in Condition I. Therefore, systematic ordering of stimulus sets in the programmed transitivity induction protocol

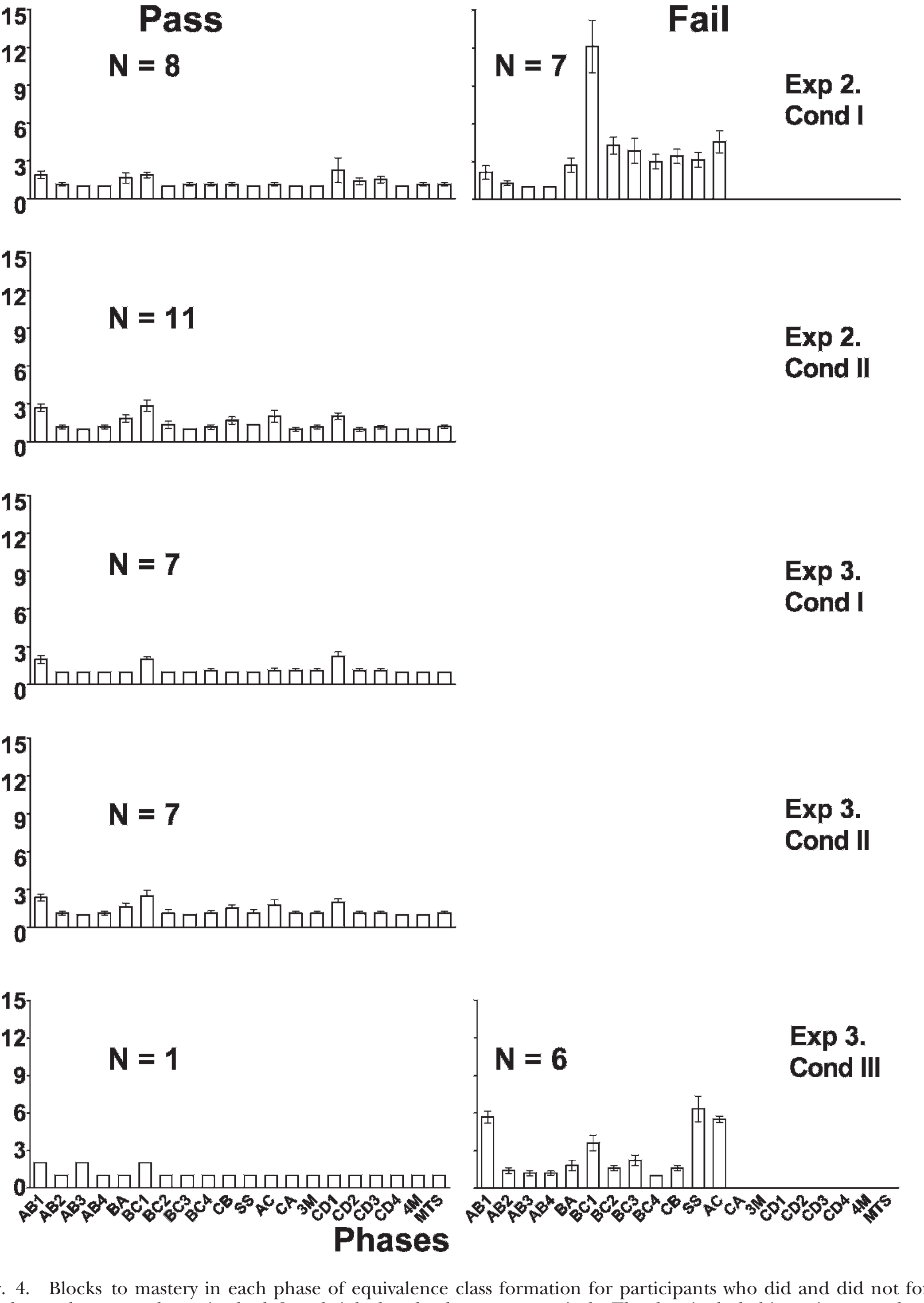

Fig. 4. Blocks to mastery in each phase of equivalence class formation for participants who did and did not form equivalence classes are shown in the left and right hand columns, respectively. The data included in a given panel were averaged for all participants included in the condition. The abscissae for all graphs indicate the phases used during equivalence class induction. AB1, AB2, AB3, and AB4 refer to training conditions in which feedback was provided for 100%, 75%, 25%, and 0% of the trials in a block, respectively, and likewise for the training of the other baseline relations. Data in each row are for different conditions in Experiments 2 and 3 and are indicated by the labels in the rightmost

was a strong determinant of the efficacy of the PTI protocol.

It is not clear, however, what parameters of the ordering of phases and the stimuli used across phases were critical for the enhancement of subsequent formation of equivalence classes. That could be determined by studying the effects of a number of variations of the PTI protocol. These could include variation in the ordering of phases while holding constant the stimuli included in each phase, holding the logical ordering of the phases constant with a manipulation of the stimulus sets across phases, or by varying the number of phases holding order constant.

CROSS-EXPERIMENT ANALYSIS OF EQUIVALENCE CLASS FORMATION

The analyses presented above in Experiments 1, 2, and 3 identified variables that influenced likelihood of equivalence class formation, but did not provide a detailed characterization of performances engendered by each phase of training and testing during class formation. That information is provided in the present section for the participants of Experiments 2 and 3. Because the procedure used in Experiment 1 was replicated in Condition 1 of Experiment 2, information is not provided separately for Experiment 1.

Performances during the emergence of equivalence classes. Figure 4 presents the performances in each phase of training and testing during the establishment of the three- and four-member equivalence classes and during testing under the DMTS condition. The panels in the left and right columns show data for participants who did and did not form equivalence classes, respectively.

Data in the two top rows are for participants in Experiment 2. The first row presents data for the participants who received trial familiarization training (Condition I) while the second row presents data for the participants who received PTI (Condition II). The third, fourth, and fifth rows present data for the participants in Experiment 3, Conditions I, II and III, respectively.

From these data, several general observations can be made. Data for participants who formed equivalence classes were similar, regardless of the form of preliminary training. Data for participants who did not form equivalence classes were likewise similar, regardless of the form of preliminary training. Data for participants who did and did not form classes, however, showed many differences.

The following commonalities were observed for participants who formed equivalence classes, as shown in Figure 4. First, all of the baseline relations were established in few training blocks, demonstrating rapid acquisition. Second, the baseline relations were maintained with reductions of feedback. That is, the conditional discriminative control exerted by the baseline relations was resistant to disruption. Third, immediate emergence occurred for all derived relations probes. Fourth, class consistent responding emerged immediately during the generalization test with probes presented in a DMTS format. Finally, there was a minimal amount of intersubject variation, as evidenced by the very small standard error bars. These findings were obtained for 33 participants.

Among participants who did not form equivalence classes, the following commonalities were observed. First, the AB baseline relations were acquired in few training blocks regardless of condition, but the acquisition of the BC relations took many more blocks. In addition, the emergence of the symmetrical relations occurred on a delayed basis for participants who did not form classes, and these participants also required additional blocks to master the mixed test of symmetry. Finally, no participant who failed to form equivalence classes successfully passed the transitivity probe. These findings were obtained for 14 participants.

A comparison of the performances for the participants who did and did not form classes illustrated the following differences. Those

←

section of each row. The N values in each panel indicate the number of participants from whom data were included in the averages. The error bars indicate +/− 1 Standard Error (SE). The absence of an error bar means that all participants performed in the same manner during that phase. See text and tables for further information.

who did not form classes required many more blocks to acquire the BC baseline relations. They also required many blocks to master both the symmetry and mixed symmetry probe, while the symmetrical relations emerged on an immediate basis for the participants who formed classes. Finally, participants who did not form equivalence classes failed to pass the transitivity tests, whereas all participants who formed classes passed these tests, demonstrating essentially immediate emergence.

These comparisons suggest that the programmed transitivity induction procedures induced a range of stimulus control topographies. The differences between those who formed classes and those who did not indicates that exposure to the programmed transitivity induction protocol established stimulus control repertoires that enabled the rapid acquisition of new conditional discriminations, resisted disruption of baseline relations in the face of feedback reduction, and promoted the immediate emergence of symmetrical and transitive relations.

The NO responding evoked by within-class transitivity probes. In each of the experiments, when a participant failed to form equivalence classes, the failure usually involved the evocation of the *NO* response by the within-class transitivity probes instead of the correct *YES* response. This occurred along with the correct evocation of the *NO* response by the cross-class transitivity probes. Two theoretical accounts that could explain this phenomenon are considered next.

First, according to the standard view, the A1 and C1 stimuli would be linked through training of the within-class baseline relations A1–B1 and B1–C1. Since both of the relations occasioned the reinforcement of the *YES* response, the A1–C1 probe should also have evoked the *YES* response. Contrary to expectations, for some participants the within-class transitivity probes evoked the *NO* response. This outcome could be explained by assuming that the A1 and C1 stimuli were linked by the cross-class baseline relations A1–B2 and B2–C1, both of which shared B2, the nodal stimulus from the other class. Since both of these relations occasioned reinforcement of the *NO* response, the A1–C1 probe would also evoke the *NO* response. This source of stimulus control, then, would have interfered with the subsequent formation of new equivalence classes. Currently, however, these distinctions cannot be made empirically because the present experiments did not provide a means of tracking the baseline relations that were being attended to while solving the within-class transitivity probes.

This account is also challenged when applied to the mediation of performances evoked by the cross-class probes. If the within-class transitivity probes were mediated by attention to the two cross-class baseline relations, a similar process should also account for the evocation of the *NO* response by the cross-class transitivity probes. For example, A1–C2 could be mediated by A1–B2 (which occasioned reinforcement of the *NO* response) and B2–C2 (which occasioned reinforcement of the *YES* response). Thus, the A1 → C2 probe should evoke the *YES* and *NO* responses with equal likelihood. Instead, cross-class transitivity probes consistently evoked a *NO* response. This outcome, then, is not explained by the above analysis, though it might be explained by the theory that the *NO* response is reliably evoked by a transitivity probe if at least one of the linking baseline relations reinforced the *NO* response. Regardless of this alternative, the proposed explanation for the evocation of the incorrect *NO* responses by the within-class transitivity probes does not also account for the correct evocation of the *NO* responses by cross-class transitivity probes. The theoretical account, then, does not provide a consistent explanation of the responses that were evoked by within- and cross-class transitivity probes.

Finally, this account is challenged by the results of Conditions I and II in Experiment 3. If this theory were correct, one would expect that participants who received direct training of the within-class transitive relations would perform better than those who did not receive such training. As discussed previously, however, this was not the case. Participants in Condition II showed immediate emergence of the transitive relation on within-class probes, correctly responding *YES* on these trials. This indicates that even without direct training of A1 → C1 and A2 → C2, these relations were mediated by the within-class baseline relations.

A second possible explanation for the incorrect *NO* response on within-class transitivity probes could be that the *NO* response evoked by both the within- and cross-class transitivity probes indicated that the stimuli had not been presented together during prior training. This interpretation was proposed by Fields et al. (1997), and has received partial support from verbal reports of some participants during postexperimental interviews. If true, the failure of transitivity, then, would have been caused by inadvertent control of the *NO* response by novel combinations of stimuli in a trial rather than the absence of a transitivity repertoire. By implication, then, the programmed transitivity induction protocol would have been effective because it taught participants to use the *NO* response to indicate membership of stimuli in the different classes, and suppressed its use to indicate novelty of the stimulus pairs. Accordingly, the protocol enhanced the subsequent formation of new equivalence classes by the elimination of a stimulus control topography that interfered with control of behavior by class-based stimulus control topographies. Finally, this analysis suggests that class formation could also be enhanced, perhaps to equal degree, with a preclass formation protocol that would directly train participants to use the *NO* response for its experimenter-intended purpose, absent the induction of a generalized transitivity repertoire. This account receives indirect support from the results of Condition II in Experiment 3 where preliminary training did not include the presentation of transitivity trials and thus did not provide direct training of transitive relations.

To summarize, these theoretical accounts suggest that failures of class formation were due to unexpected stimulus control repertoires that interfered with class-based performances evoked by transitivity probes and thus the formation of equivalence classes. In addition, the results of Experiment 3 suggest that the efficacy of the preliminary training protocol was not produced by the inclusion of transitivity training, but rather by the systematic ordering of stimulus sets in that protocol and the linkage of stimulus sets by nodal stimuli. Indeed, these latter manipulations probably taught participants to attend to within-class relations when responding to within-class transitive and equivalence relations probes and to cross-class relations when responding to cross-class transitive and equivalence relations probes, and thus to respond in a manner that reflected control of behavior by class membership.

GENERAL DISCUSSION

The results of the experiments as a whole have implications for three general issues: (a) the reliability of equivalence class formation, (b) the format independence of relations among stimuli in equivalence classes, and (c) the explanatory power of an equivalence-based analysis of complex human behavior. Each is discussed in order.

Reliability of equivalence class formation. Matching-to-sample is the most commonly used format for training and testing when attempting to establish equivalence classes. When using an MTS format, early research found that the reliability of equivalence class formation was rather variable. Many more recent studies have found that the likelihood of class formation was substantially improved by the incorporation of a variety of particular training and testing strategies and response topographies in the procedures used to form classes, such as those mentioned in the Introduction.

The results of the present experiments paint a similar picture for equivalence class formation when trials are presented in a trace SP2R format. Under some preliminary training conditions, the likelihood of class formation was modest while other preliminary training conditions very reliably resulted in class formation. Regardless of trial format, then, appropriate prior training can substantially enhance the likelihood of equivalence class formation.

Format independence of equivalence classes. All of the participants in Experiments 1, 2, and 3 who formed equivalence classes, then immediately demonstrated class-indicative responding when equivalence class relations were probed in a two-choice DMTS format. As noted in the Method section of Experiment 1, the instructions for the DMTS transfer test were minimal. Thus, the instant generalization of class indicative performances to DMTS trials attests to the format independence of the baseline and derived relations that emerged in the trace SP2R format.

Explanatory power of equivalence class accounts of complex behavior. As noted in the Introduction, equivalence class formation has been posited as a behavioral account of complex forms of human relational responding (Sidman, 1994; 2000). To be used as a broad-based account, it is necessary to show that equivalence classes can be formed with reliability in a number of different training and testing formats. The results of Experiments 2 and 3 showed that equivalence classes can be formed reliably using trials presented in an SP2R format. Thus, equivalence classes can be formed with high likelihood in at least two formats: MTS and SP2R. The results of these experiments, then, bolster the explanatory power of equivalence-based accounts of complex human behavior.

Summary. Three experiments identified variables that influenced the formation of equivalence classes where training and testing were conducted using trials presented in a trace SP2R format. With minimal prior training, about 50% of participants formed classes, regardless of the labels used to identify the response options. In contrast, close to 100% of participants formed equivalence classes after preliminary training with one of two forms of a PTI protocol. The efficacy of both protocols did not depend on the inclusion of transitive relations trials but was dependent on the ordering of stimulus sets in the protocol. Regardless of prior training, performances were highly similar among participants who formed classes, and likewise for those who did not, Performances among subjects who did and did not form classes, however, were highly dissimilar. The successful completion of the PTI protocols, then, probably established or strengthened stimulus control repertoires that (a) enabled the rapid acquisition of new conditional discriminations, (b) enhanced resistance to disruption of baseline relations during feedback reduction, (c) promoted the immediate emergence of symmetrical relations, and (d) increased the emergence of transitive relations mediated by within-class baseline relations. These stimulus control topographies were probably components of the current repertoires of the participants who formed equivalence classes without prior training. The results of these experiments strengthened explanatory accounts of the emergence of complex forms of human behavior in terms of equivalence class formation.

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APPENDIX A

Trial familiarization training protocol (TFT) in Experiment 1, including the stimulus sets, temporal (Temp) and positional (Pos) parameters, prompt and feedback (FB) levels, and number of trials per block for each phase.

Phase	Set #	Temp	Pos	Prompt	FB	Relations	Trials/Block
1	1&2	delay	diff	full	100	Aw → Bw	8
2	‘‘	‘‘	‘‘	partial	‘‘	Aw → Bw	8
3	‘‘	‘‘	‘‘	none	‘‘	Aw → Bw	8
4	‘‘	trace	‘‘	‘‘	‘‘	Aw → Bw	8
5	‘‘	‘‘	same	‘‘	‘‘	Aw → Bw	8
6	‘‘	‘‘	‘‘	‘‘	‘‘	Aw → Cn	8
7	‘‘	‘‘	‘‘	‘‘	‘‘	Dn → Cn	8
8	‘‘	‘‘	‘‘	‘‘	75	Dn → Cn	8
9	‘‘	‘‘	‘‘	‘‘	25	Dn → Cn	8
10	‘‘	‘‘	‘‘	‘‘	0	Dn → Cn	8

APPENDIX B

All training and testing trials in the equivalence class formation procedure, including the feedback (FB) levels, the relation (Rel) trained or tested, and the number of within- and cross-class trials per block for each phase. Each box is for a separate phase in the protocol. Phases progress down and then across columns from left to right. Entries in bold font are new relations.

Type	FB	Rel	Class	Sa	Co	Trials	Type	FB	Rel	Class	Sa	Co	Trials
BL	100	AB	**within**	**A1**	**B1**	**4**	2SYM	0	AB	within	A1	B1	2
				A2	**B2**	**4**					A2	B2	2
			cross	**A1**	**B2**	**4**				cross	A1	B2	2
				A2	**B1**	**4**					A2	B1	2
<FB	75-0	AB	within	A1	B1	2			BC	within	B1	C1	2
				A2	B2	2					B2	C2	2
			cross	A1	B2	2				cross	B1	C2	2
				A2	B1	2					B2	C1	2
SYM	0	AB	within	A1	B1	4			CB	within	C1	B1	2
				A2	B2	4					C2	B2	2
			cross	A1	B2	4				cross	C1	B2	2
				A2	B1	4					C2	B1	2
		BA	**within**	**B1**	**A1**	**4**			BA	within	B1	A1	2
				B2	**A2**	**4**					B2	A2	2
			cross	**B1**	**A2**	**4**				cross	B1	A2	2
				B2	**A1**	**4**					B2	A1	2
BL	100	AB	within	A1	B1	1	TTY	0	AB	within	A1	B1	2
				A1	B2	1					A2	B2	2
			cross	A2	B2	1				cross	A1	B2	2
				A2	B1	1					A2	B1	2
		BC	**within**	**B1**	**C1**	**3**			BC	within	B1	C1	2
				B2	**C2**	**3**					B2	C2	2
			cross	**B1**	**C2**	**3**				cross	B1	C2	2
				B2	**C1**	**3**					B2	C1	2
<FB	75-0	BC	within	A1	B1	1			**AC**	**within**	**A1**	**C1**	**4**
				A2	B2	1					**A2**	**C2**	**4**
			cross	A1	B2	1				**cross**	**A1**	**C2**	**4**
				A2	B1	1					**A2**	**C1**	**4**
			within	B1	C1	1	EQV	0	AB	within	A1	B1	1
				B2	C2	1					A2	B2	1
			cross	B1	C2	1				cross	A1	B2	1
				B2	C1	1					A2	B1	1
SYM	0	AB	within	A1	B1	2			BC	within	B1	C1	1
				A2	B2	2					B2	C2	1
			cross	A1	B2	2				cross	B1	C2	1
				A2	B1	2					B2	C1	1
		BC	within	B1	C1	2			**CA**	**within**	**C1**	**A1**	**2**
				B2	C2	2					**C2**	**A2**	**2**
			cross	B1	C2	2				**cross**	**C1**	**A2**	**2**
				B2	C1	2					**C2**	**A1**	**2**
		CB	**within**	**C1**	**B1**	**4**							
				C2	**B2**	**4**							
			cross	**C1**	**B2**	**4**							
				C2	**B1**	**4**							

APPENDIX B

(*Continued*)

Type	FB	Rel	Class	Sa	Co	Trials	Type	FB	Rel	Class	Sa	Co	Trials
3-MIX	0	AB	within	A1	B1	2	4-MIX	0	AB	within	A1	B1	1
				A2	B2	2					A2	B2	1
			cross	A1	B2	2				cross	A1	B2	1
				A2	B1	2					A2	B1	1
		BC	within	B1	C1	2			BC	within	B1	C1	1
				B2	C2	2					B2	C2	1
			cross	B1	C2	2				cross	B1	C2	1
				B2	C1	2					B2	C1	1
		BA	within	B1	A1	1			CD	within	C1	D1	1
				B2	A2	1					C1	D2	1
			cross	B1	A2	1				within	C2	D2	1
				B2	A1	1					C2	D1	1
		CB	within	C1	B1	1			BA	within	B1	A1	2
				C2	B2	1					B1	A2	2
			cross	C1	B2	1				within	B2	A2	2
				C2	B1	1					B2	A1	2
		AC	within	A1	C1	1			CB	within	C1	B1	2
				A2	C2	1					C1	B2	2
			cross	A1	C2	1				within	C2	B2	2
				A2	C1	1					C2	B1	2
		CA	within	C1	A1	1			**DC**	**within**	**D1**	**C1**	**2**
				C2	A2	1					**D2**	**C2**	**2**
			cross	C1	A2	1				**cross**	**D1**	**C2**	**2**
				C2	A1	1					**D2**	**C1**	**2**
BL	100	AB	within	A1	B1	1			AC	within	A1	C1	2
				A2	B2	1					A2	C2	2
			cross	A1	B2	1				cross	A1	C2	2
				A2	B1	1					A2	C1	2
		BC	within	B1	C1	1			**BD**	**within**	**B1**	**D1**	**2**
				B2	C2	1					**B2**	**C2**	**2**
			cross	B1	C2	1				**cross**	**B1**	**D2**	**2**
				B2	C1	1					**B2**	**D1**	**2**
		CD	**within**	**C1**	**D1**	**2**			CA	within	C1	A1	2
				C2	**D2**	**2**					C2	A2	2
			cross	**C1**	**D2**	**2**				cross	C1	A2	2
				C2	**D1**	**2**					C2	A1	2
<FB	75-0	AB	within	A1	B1	1			**DB**	**within**	**D1**	**B1**	**2**
				A2	B2	1					**D2**	**B2**	**2**
			cross	A1	B2	1				**cross**	**D1**	**B2**	**2**
				A2	B1	1					**D1**	**B1**	**2**
		BC	within	B1	C1	1			**AD**	**within**	**A1**	**D1**	**2**
				B2	C2	1					**A2**	**D2**	**2**
			cross	B1	C2	1				**cross**	**A1**	**D2**	**2**
				B2	C1	1					**A2**	**D1**	**2**
		CD	within	C1	D1	2			**DA**	**within**	**D1**	**A1**	**2**
				C2	D2	2					**D2**	**A2**	**2**
			cross	C1	D2	2				**cross**	**D1**	**A2**	**2**
				C2	D1	2					**D1**	**A1**	**2**

APPENDIX C

All probes presented in the DMTS generalization test block.

Relational Type	Specific Relation	Sa	Co+	Co−	Trials
Baseline	AB	A1	B1	B2	2
		A2	B2	B1	2
Baseline	BC	B1	C1	C2	2
		B2	C2	C1	2
Baseline	CD	C1	D1	D2	2
		C2	D2	D1	2
Symmetry	BA	B1	A1	A2	2
		B2	A2	A1	2
Symmetry	CB	C1	B1	B2	2
		C2	B2	B1	2
Symmetry	DC	D1	C1	C2	2
		D2	C2	C1	2
1-node Transitivity	AC	A1	C1	C2	2
		A2	C2	C1	2
1-node Transitivity	BD	B1	D1	D2	2
		B2	D2	D1	2
1-node Equivalence	CA	C1	A1	A1	2
		C2	A2	A1	2
1-node Equivalence	DB	D1	B1	B2	2
		D2	B2	B1	2
2-node Transitivity	AD	A1	D1	D2	2
		A2	D2	D1	2
2-node Equivalence	DA	D1	D1	D2	2
		D2	D2	D1	2

APPENDIX D

Diagrammatic representation of programmed transitivity induction in Experiments 2 and 3.

Phase	Set #	Temp	Pos	Prmpt	FB	Relations: Baselines		Relations: Transitive	Trials per Relation
1	***1&2***	**Delay**	***Diff***	***none***	***100***	Aw → Bw			8
							Bw → Cw		**8**
						Aw → Bw,	Bw → Cw		8,8
								Aw → Cw	**8**
						Aw → Bw,	Bw → Cw,	Aw → Cw	4,4,8
2	***3&4***	‘‘	‘‘	”	‘‘	**Aw → Bw**			**8**
							Bw → Cw		**8**
						Aw → Bw,	Bw → Cw		8,8
								Aw → Cw	**8**
						Aw → Bw,	Bw → Cw,	Aw → Cw	4,4,8
3	‘‘	‘‘	‘‘	‘‘	‘‘	Aw → Bw			8
							Bw → Dn		8
						Aw → Bw,	Bw → Dn		8,8
								Aw → Dn	8
						Aw → Bw,	Bw → Dn,	Aw → Dn	4,4,8
4	‘‘					Aw → Dn			8
							Dn → En		8
						Aw → Dn,	Dn → En		8,8
								Aw → En	8
						Aw → Dn,	Dn → En,	Aw → En	4,4,8
5	‘‘	‘‘	‘‘	‘‘	‘‘	Dn → En			8
						En → Fn			8
						Dn → En,	En → Fn		8,8
								Dn → Fn	8
						Dn → En,	En → Fn,	Dn → Fn	4,4,8
6	***5&6***	‘‘	‘‘	‘‘	‘‘	An → Bn			8
							Bn → Cn		8
						An → Bn,	Bn → Cn		8,8
								An → Cn	8
						An → Bn,	Bn → Cn,	An → Cn	4,4,8
7	***7&8***	‘‘	‘‘	‘‘	‘‘	An → Bn			8
					100-0	An → Bn,	Bn → Cn		8,8
					0	An → Bn,	Bn → Cn,	An → Cn **(1)**	4,4,8
					100	An → Bn,	Bn → Cn,	An → Cn	4,4,,8
8	**“**	***Trace***	‘‘	‘‘	‘‘	An → Bn			8
					100-0	An → Bn,	Bn → Cn		8,8
					0	An → Bn,	Bn → Cn,	An → Cn **(1)**	4,4,8
					100	An → Bn,	Bn → Cn,	An → Cn	4,4,8
9	**“**	‘‘	***Same***	‘‘	‘‘	An → Bn			8
					100-0	An → Bn,	Bn → Cn		8,8
					0	An → Bn,	Bn → Cn,	An → Cn **(1)**	4,4,8
					100	An → Bn,	Bn → Cn,	An→Cn	4,4,8

APPENDIX E

Diagrammatic representation of programmed transitivity induction in Experiment 3, Condition I, including the stimulus sets, temporal (Temp) and positional (Pos) parameters, feedback (FB) levels, and number of trials per block for each phase.

Phase	Set #	Temp	Pos	FB	Relations: Baselines		Relations: Transitive	Trials per Relation
1	1&2	Delay	Diff	100	Aw → Bw			8
						Bw → Cw		8
					Aw → Bw,	Bw → Cw		8,8
							Aw → Cw	8
					Aw → Bw,	Bw → Cw,	Aw → Cw	4,4,8
2	3&4	‘‘	‘‘	‘‘	Aw → Bw			8
						Bw → Cw		8
					Aw → Bw,	Bw → Cw		8,8
							Aw → Cw	8
					Aw → Bw,	Bw → Cw,	Aw → Cw	4,4,8
3	‘‘	‘‘	‘‘	‘‘	Aw → Bw			8
						Bw → Dn		8
					Aw → Bw,	Bw → Dn		8,8
							Aw → Dn	8
					Aw → Bw,	Bw → Dn,	Aw → Dn	4,4,8
4	‘‘	‘‘	‘‘	‘‘	Aw → Dn			8
						Dn → En		8
					Aw → Dn,	Dn → En		8,8
							Aw → En	8
					Aw → Dn,	Dn → En,	Aw → En	4,4,8
5	‘‘	‘‘	‘‘	‘‘	Dn → En			8
						En → Fn		8
					Dn → En,	En → Fn		8,8
							Dn → Fn	8
					Dn → En,	En → Fn,	Dn → Fn	4,4,8
6	5&6	‘‘	‘‘	‘‘	An → Bn			8
						Bn → Cn		8
					An → Bn,	Bn → Cn		8,8
							An → Cn	8
					An → Bn,	Bn → Cn,	An → Cn	4,4,8
7	7&8	Trace	‘‘	‘‘	An → Bn			8
					An → Bn,	Bn → Cn		8,8
					An → Bn,	Bn → Cn,	An → Cn	4,4,8
					An → Bn,	Bn → Cn,	An → Cn	4,4,,8
8	‘‘	‘‘	Same	‘‘	An → Bn			8
					An → Bn,	Bn → Cn		8,8
					An → Bn,	Bn → Cn,	An → Cn	4,4,8
					An → Bn,	Bn → Cn,	An → Cn	4,4,8
9	‘‘	‘‘	‘‘	‘‘	An → Bn			8
					An → Bn,	Bn → Cn		8,8
					An → Bn,	Bn → Cn,	An → Cn	4,4,8
				100-0	An → Bn,	Bn → Cn,	An → Cn	4,4,8

APPENDIX F

Diagrammatic representation of programmed transitivity induction in Experiment 3, Condition III, including the stimulus sets, temporal (Temp) and positional (Pos) parameters, feedback (FB) levels, and number of trials per block for each phase.

					Relations			
Phase	Set #	Temp	Pos	FB	Baselines		Transitive	Trials per Relation
4	3&4	Delay	Diff	100	Aw → Dn			8
						Dn → En		8
					Aw → Dn,	Dn → En		8,8
							Aw → En	8
					Aw → Dn,	Dn → En,	Aw → En	4,4,8
2	‘‘	‘‘	‘‘	‘‘	Aw → Bw			8
						Bw → Cw		8
					Aw → Bw,	Bw → Cw		8,8
							Aw → Cw	8
					Aw → Bw,	Bw → Cw,	Aw → Cw	4,4,8
5	‘‘	‘‘	‘‘	‘‘	Dn → En			8
							En → Fn	8
					Dn → En		En → Fn	8,8
							Dn → Fn	8
					Dn → En	En → Fn	Dn → Fn	4,4,8
8	7&8	Trace	Same	‘‘	An → Bn			8
					An → Bn	Bn → Cn		8,8
					An → Bn	Bn → Cn	An → Cn	4,4,8
					An → Bn	Bn → Cn	An → Cn	4,4,8
1	1&2	Del	Diff	‘‘	Aw → Bw			8
						Bw → Cw		8
					Aw → Bw	Bw → Cw		8,8
							Aw → Cw	8
					Aw → Bw	Bw → Cw	Aw → Cw	4,4,8
6	5&6	‘‘	‘‘	‘‘	An → Bn			8
						Bn → Cn		8
					An → Bn	Bn → Cn		8,8
							An → Cn	8
					An → Bn	Bn → Cn	An → Cn	4,4,8
3	3&4	‘‘	‘‘	:	Aw → Bw			8
						Bw → Dn		8
					Aw → Bw	Bw → Dn		8,8
							Aw → Bn	8
					Aw → Bw	Bw → Dn	Aw → Dn	4,4,8
9	7&8	Trace	Same	‘‘	An → Bn			8
					An → Bn	Bn → Cn		8,8
					An → Bn	Bn → Cn	An → Cn	4,4,8
				100-0	An → Bn	Bn → Cn	An → Cn	4,4,8
7	‘‘	‘‘	‘‘	100	An → Bn			8
					An → Bn	Bn → Cn		8,8
					An → Bn	Bn → Cn	An → Cn	4,4,8
				100-0	An → Bn	Bn → Cn	An → Cn	4,4,8